Test yourself on basic semiconductor carrier ideas

1. What are the "free carriers" (of concentrations n and p) in a semiconductor?
   (a) Holes in the conduction band and electrons in the valence band
   (b) Electrons in the conduction band and holes in the valence band
   (c) Both electrons and holes in the conduction band
   (d) Holes in the valence band and all electrons in the sample.

2. Consider a piece of pure Ge crystal with atomic concentration N. Which of the following statements about electron concentration n and hole concentration p are true?
   (a) $n = p$
   (b) $n \gg p$
   (c) $n \approx N$
   (d) $n \ll N$

3. n-type semiconductors
   (a) are negatively charged.
   (b) have more electrons than holes.
   (c) contain negative dopant ions.
   (d) have no holes.

4. Consider a Si semiconductor where two types of dopants occur throughout the sample; $N_D = 10^{14}$ cm^{-3} of As and $N_A = 10^{15}$ cm^{-3} of B. Which statements about the semiconductor are true?
   (a) In the sample, $p = N_A$ and $n = N_D$ (assuming full ionization)
   (b) In the sample, $np = n_i^2$
   (c) The sample is intrinsic
   (d) The sample is p-type

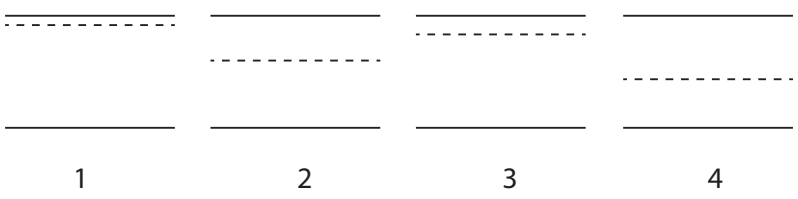
5. In a p-type sample at room temperature, we typically find that (E_F, E_A, E_C measured from E_V)
   (a) $E_F > E_A$
   (b) $kT > E_F$
   (c) $kT > E_g$
   (d) $E_C - E_F > E_F - E_V$

6. In a n-type sample at room temperature, we typically find that

   (a) $F(E_C) \ll 1$
   (b) $F(E_D) \ll 1$
   (c) $F(E_V) \ll 1$
   (d) $F(E_F) \ll 1$

7. Consider figure 25 on page 39.

   (a) The majority carriers are electrons
   (b) The majority carriers are holes
   (c) In the extrinsic region, the minority charge carrier concentration is constant
   (d) In the intrinsic region, the minority charge carrier concentration is similar to the majority charge carrier concentration.



8. Consider the hole concentration p in four Si samples 1– 4. They are all at the same temperature. The full lines are the band edges and the dashed line is the Fermi level.

   Which statement about hole concentration p in the four samples (p_1- p_4) is true?

   (a) $p = 0$ in all samples except sample 4 ($p_4 > 0$)
   (b) $p_1 > p_3 > p_2 > p_4$
   (c) $p_4 > p_2 > p_3 > p_1$
   (d) It is impossible to tell since we don't know if any of them are doped with acceptors.

9. How many atoms are there in 1 cm^3 of Si? If the Si is doped to $N_D = 10^{17}$ cm^{-3}, what is the ratio of the number of dopants to the number of Si-atoms?

10. Consider a pn-junction in thermal equilibrium and at operational temperature. At the junction there is a depletion region, and outside that there are neutral p- and n-regions. Fill in the blanks in the following text. Words are suggested for each blank – choose the appropriate one.

    Considering the depletion region in the p-type material, there is a net (a) charge. The region is depleted of free (b) and the remaining charge originates from the ionized (c). Moving further away from the junction into the neutral p-type material, the material is uncharged. Here we have free (d) and (e) acceptors. The concentration of carriers is (f) that of the acceptors.

    (a) positive, negative

    (b) electrons, holes, donors, acceptors

    (c) acceptors, donors, holes, electrons

    (d) holes, electrons, dopants

    (e) ionized, positive, neutral

    (f) less than, larger than, equal to

    In the n-type material, there are electrons and (g) donors. In the neutral region, the (h) electrons and the (i) donors cancel out with respect to charge. In the depleted part of the n-type semiconductor, close to the junction, the semiconductor has a net (j) charge. Here, the semiconductor is depleted of (k) and the net charge is due to (l).

    (g) ionized, neutral

    (h) free, fixed

    (i) positive and free, positive and fixed, neutral and fixed, neutral and free

    (j) negative, positive, neutral

    (k) donors, electrons, acceptors

    (l) holes, ionized donors, unionized donors

ANSWERS

1. b
2. a, d
3. b
4. b, d
5. a, d
6. a, b
7. a, d
8. c
9. about $5 \cdot 10^{22}$ cm^{-3} atoms in the sample. Ratio $10^{17}/5 \cdot 10^{22} = 2 \cdot 10^{-6}$
10. (a) negative
    (b) holes
    (c) acceptors
    (d) holes
    (e) ionized
    (f) equal to
    (g) ionized
    (h) free
    (i) positive and fixed
    (j) positive
    (k) electrons
    (l) ionized donors